# *Human Factors Design Considerations for the Autonomous Operations Planner*

**Richard Barhydt**
**NASA Langley Research Center, Hampton, VA**

**Karthik Krishnamurthy**
**Titan Corporation, Hampton, VA**




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# Distributed Air/Ground Traffic Management (DAG-TM)



- **Long range focus designed to significantly improve system capacity while maintaining or improving safety.**
- **DAG-TM *En Route Free Maneuvering* component represents paradigm shift from centralized to distributed traffic management.**
  - Autonomous aircraft flying under "Autonomous Flight Rules" (AFR) responsible for maintaining separation from all other traffic (AFR and IFR), while meeting traffic flow management constraints.
  - Air traffic service provider continues to provide traffic separation between IFR aircraft and assigns constraints to all aircraft for flow management.

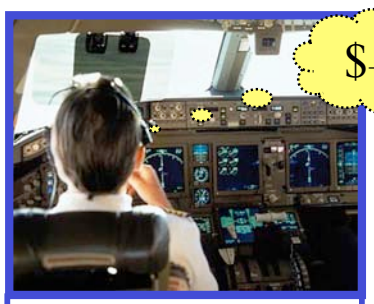
# DAG-TM Concept

*Distributed Air / Ground Traffic Management*

- **System capacity, airspace user flexibility, and user efficiency improved through**
  - Sharing information related to flight intent, traffic, and the airspace environment.
  - Collaborative decision making among all involved system participants.
  - Distributing decision authority to the most appropriate decision maker.

# DAG-TM Operational Environment

## *Distributed Air / Ground Traffic Management*




**Autonomous (AFR) Aircraft**

**Aeronautical Operational Control**

*Fleet management*

*Cost management, Passenger comfort*

***Concept Integrates:***

***Mixed operations***
***Operational constraints***
***User flexibility***

*IFR priority*

*Airborne separation*

*Hazard avoidance*

*Priority rules*

*Special Use Airspace avoidance*

*IFR trajectory management*

*Maneuver restrictions*

*Crossing restrictions*

*Terminal area*

***User-determined optimal trajectory***

*IFR and AFR traffic flow management*

**Managed (IFR) Aircraft**

**Air Traffic Service Provider**

Richard Barhydt richard.barhydt@nasa.gov

# Prototype ASAS Enables DAG-TM



- **DAG-TM enabled through Airborne Separation Assurance System (ASAS).**
- **Autonomous Operations Planner (AOP), developed at NASA Langley, functions as prototype ASAS.**
  - Uses currently available and anticipated information.
  - Compatible with existing aircraft systems and industry standards.
  - Supports airborne conflict management.
  - Conforms to established flight deck conventions and human factors guidelines.

# Primary AOP Functions

*Distributed Air / Ground Traffic Management*

- **Conflict detection.**
  - Other aircraft.
  - Airspace hazards (special use airspace, hazardous weather regions.)
- **Conflict prevention.**
  - Prevent maneuvers that would create near-term conflicts with other aircraft or airspace hazards.
    - No-fly zones.
    - Conflicts on provisional routes.
- **Conflict resolution and flow constraint conformance.**
  - Resolve conflicts with all other aircraft, airspace hazards, while meeting constraints (altitude, speed, time).
  - Strategic and tactical options.

# AOP Human Factors Design Features

*Distributed Air / Ground Traffic Management*

- **Support AFR pilot's DAG-TM responsibilities.**
- **Conform to established flight deck conventions, pilot interfaces, and procedures.**
- **Integrate effectively with other information provided to pilot.**
- **Provide graded alerts and corresponding procedures based on time to conflict.**
- **Provide resolution options based on how pilot is currently flying airplane.**
  - Tactical/strategic flight guidance.
- **Facilitate training and line-oriented operation.**
- **Operate under real-world constraints.**
  - Aircraft performance limitations.
  - Trajectory uncertainties.
  - Imperfect data availability.

# Pilot Workstation Displays and Controls

*Distributed Air / Ground Traffic Management*


- **Displays and controls modeled after B-777.**
- **AOP pilot interface through Control Display Unit (CDU) and Traffic Display Control Panel**

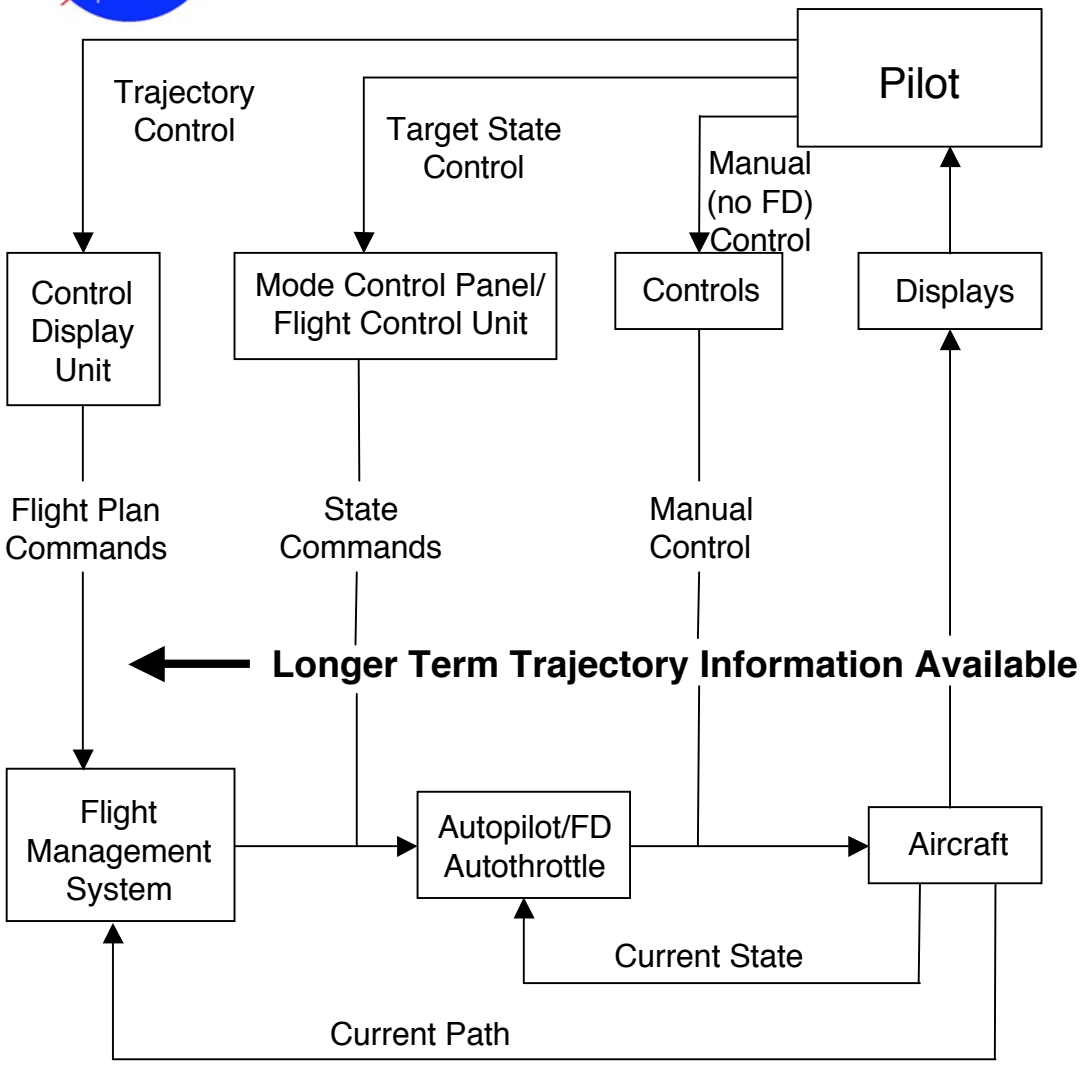
# AOP Trajectory Processing Considerations



- **Uses *command trajectory* as basis for conflict management functions.**
  - Predicted path that aircraft will fly assuming pilot does not change current automation modes or settings.
  - Recommended by various forums (FAA/Eurocontrol Intent TIM, RTCA ADS-B MASPS).
  - Considers aircraft performance, autoflight mode logic, winds.
  - Integrates target states from multiple aircraft systems:
    - Flight Management System (FMS)
    - Control Display Unit (CDU)
    - Mode Control Panel (MCP)
    - Flight Control Computer (FCC)

# Information Availability and Aircraft Control States

*Distributed Air / Ground Traffic Management*




FD: Flight Director

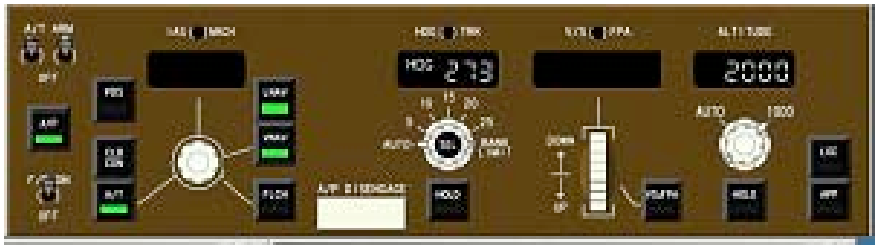
- **Conflicts predicted based on available intent information from ownship and traffic aircraft.**
- **Resolutions consistent with aircraft's current control state.**
- **Three primary control states:**
  - Manual (no flight director).
  - Target State.
    - One horizontal and vertical target available.
  - Trajectory.
    - Multiple horizontal and vertical targets available.

**Richard Barhydt richard.barhydt@nasa.gov**

# AOP Resolution Strategies



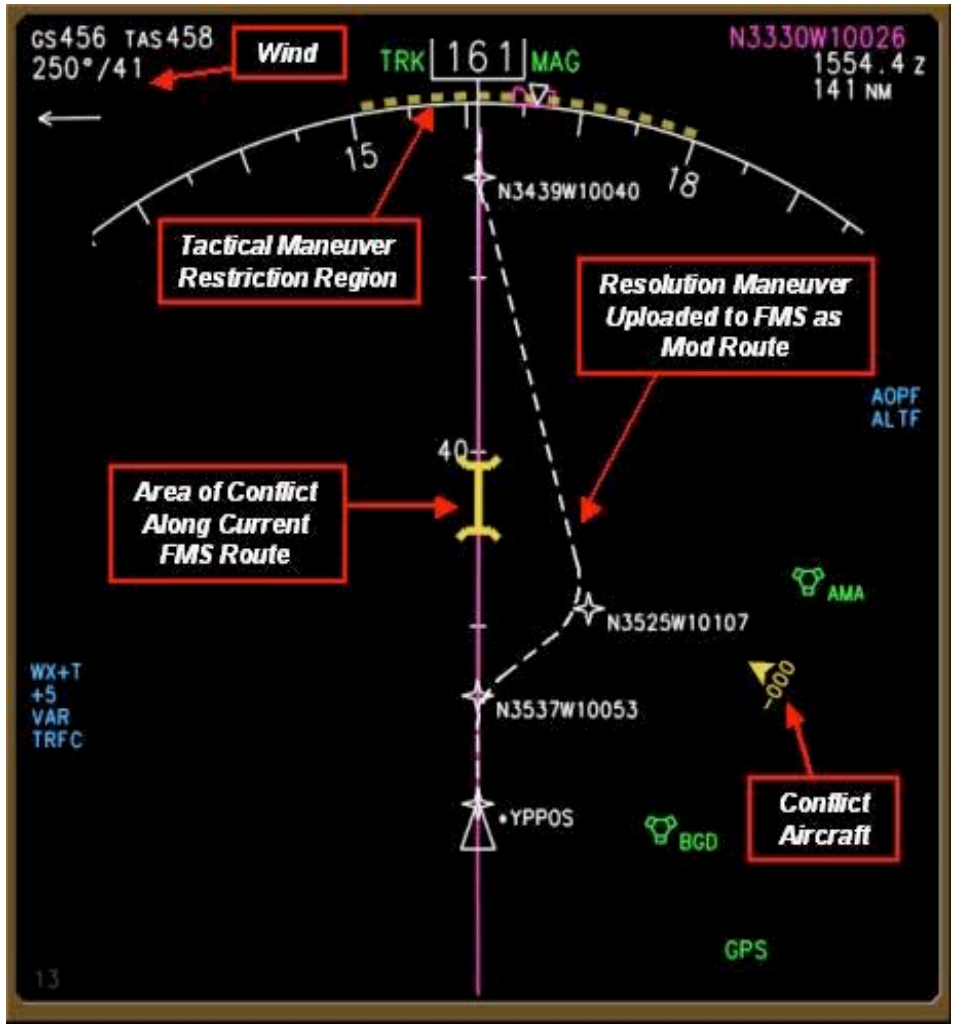
- **Resolutions allow pilot to fly aircraft in current control state/flight mode.**
  - *Tactical* (Target State control): Mode Control Panel fly-to heading, vertical speed, and altitude commands.)




  - *Strategic* (Trajectory control): Flight Management System modified routes.

# Navigation Display with Conflict Resolution

*Distributed Air / Ground Traffic Management*




- **Conflict Detection.**
  - Predicted separation loss along current flight path.
- **Conflict Prevention.**
  - No-fly zone.
- **Conflict Resolution.**
  - Recommended FMS mod route.
  - Consistent with pilot's current flight mode.

# Experimental Evaluation

*Distributed Air / Ground Traffic Management*

- **AOP design based on refinements from several previous human-in-the-loop experiments:**
  - "AUTRII" (2001) – comparison of tactical and strategic conflict resolutions.
  - "TCHAP" (2002) – AOP evaluation under highly-constrained or non-normal situations.
    - Tight maneuver corridors.
    - Pop-up conflicts.
    - Overly constrained conflicts.

- **Recently completed Joint Experiment between Langley and Ames Research Centers.**
  - Integrated air/ground environment with airline pilots and controllers.
  - Mixed operations (AFR and IFR) during cruise and descents to terminal area meter fix.

# AOP-related Air/Ground Experiment Results



- **Pilots provided favorable feedback on AOP functionality and user interface.**
- **Pilots used AOP effectively to meet ATC issued constraints (speed, altitude, and time) at meter fix, under varying traffic levels.**
- **Most separation violations due to missed alerts:**
  - Software error in vertical conflict detection.
  - Trajectory prediction uncertainty at transition points.
    - Top of descent.
    - Waypoint turns.
- **A few procedural issues noted:**
  - Maneuvers without properly checking for presence of near-term conflicts.
  - Failure to follow resolution guidance.

# AOP Human Factors Development Areas

*Distributed Air / Ground Traffic Management*

- **Handling conflict prediction uncertainty.**
  - Establish higher buffers for less certain trajectories:
    - Aircraft having less accurate navigation performance.
    - Open-loop trajectory change types (top of climb, top of descent, lateral path intercept).
    - Varying aircraft performance.
    - Changing environmental conditions.
- **Improving availability of strategic resolutions (recommended changes to FMS path).**
  - AOP sometimes unable to determine strategic resolution.
  - Incorporate reversion to tactical resolution when strategic resolution unavailable.

# AOP Human Factors Development Areas

*Distributed Air / Ground Traffic Management*

- **Enhanced blending of state and intent information.**
  - Blunder protection currently provided if failure to follow broadcast intent would cause near-term conflict.
  - Abrupt consideration of state vector information can lead to pop-up conflicts or false alerts.
  - Will consider TCAS design principles and conformance monitoring.

- **Integration of TCAS into AOP.**
  - Data fusion (ADS-B and TCAS surveillance).
  - Consideration of TCAS logic by AOP conflict detection routines.